Aquatic Resource Monitoring Plan for Six National Park Units in Arkansas and Missouri

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Background

The National Park Service (NPS) created a Service-wide Inventory and Monitoring (I&M) Program in 1992 for the purpose of providing sound natural resource information to park managers. In 2001, the I&M Program will be funded at a level which allows its application to parks within the Midwest Region included in the "Heartland Network." A working group consisting of 15 individuals and resource specialists from 15 parks met in early 2000 to prioritize I&M Program needs for the Heartland Network. The Heartland Working Group recognized the significance of the water-based parks in Arkansas and Missouri (Buffalo National River {BUFF} and Ozark National Scenic Riverways {ONSR}), the important water resources in several other units within the area (Pea Ridge National Military Park {PERI}, Hot Springs National Park {HOSP}, Arkansas Post National Monument {ARPO}, and George Washington Carver National Monument {GWCA}), and recommended the development of a monitoring program designed to assess river integrity and aquatic dependent resources within these units.

The Heartland Working Group defined the following goals for vital signs monitoring:

1.) determine the status and trends of the health of park ecosystems,
2.) establish normal limits of variation in park resources,
3.) provide early warning of resource decline,
4.) evaluate the effectiveness of resource management practices, and
5.) develop a predictive understanding of environmental change.

This document provides an introduction to the aquatic resources of concern in these six units (hereafter collectively referred to as ARMO), the objectives of the monitoring program, and a technical, budgetary, and logistical framework for a monitoring program which meets the program's goals and objectives. It further recognizes and addresses the regionally specific needs of the group and the site-specific priorities of individual units as defined by the Heartland Working Group. The monitoring strategy was developed utilizing the National Park Service Inventory and Monitoring Program's *Guidance for the Design of Sampling Schemes for Inventory and Monitoring of Biological Resources in National Parks,* as well as other sources of available information for design of monitoring programs. The principal author of this document is a National Park Service hydrologist with 12 years experience conducting aquatic monitoring and research, including assignments in four of the units included in this ARMO effort. Recommended monitoring strategies were developed with the assistance of numerous local experts including U.S. Geological Survey scientists, hydrologists from the NPS Water Resources Division, university professors, and park-based resource staff.

The units with the greatest need for aquatic resource monitoring are Buffalo National River in northern Arkansas and Ozark National Scenic Riverways in southern Missouri. Both parks are relatively large (>95,000 acres), have annual visitation numbers approaching one million, and were designated specifically to preserve free-flowing river's and diverse ecological communities. Because of their individual monitoring requirements, staff will be stationed at both units to focus on the needs of these river-based parks and provide results directly to unit managers. The four other units in the ARMO network lie within a 150-mile radius of Buffalo National River, and these satellite parks will be served by staff stationed at Buffalo National River.

The U.S. Geological Survey has recently developed a National Ambient Water Quality Assessment Program (NAWQA) which developed and tested aquatic monitoring protocols with many of the same goals and objectives as the National Park Service monitoring program. Several **(how many)** NAWQA sites are located within the ARMO parks, and the monitoring strategy they employ has provided valuable information for park managers. Therefore, the monitoring scheme recommended in this document utilizes NAWQA Program protocols where appropriate. The monitoring strategy also includes direct assistance from the U.S. Geological Survey where they are uniquely qualified to provide high quality data (e.g. stream gauging). Modifications to the NAWQA protocols have also been made where the parks recognize other monitoring needs, or where researchers have developed superior monitoring tools and/or approaches for park specific needs.

Introduction

Buffalo National River (BUFF) and Ozark National Scenic Riverways (ONSR) were created to preserve and interpret the free flowing Buffalo, Jacks Fork, and Current Rivers. The rivers are the primary resources of these Parks—they provide the canoeing and fishing opportunities that attract millions of visitors and support the parks' diverse biological communities. Managers are charged with preservation of the river environment; they must maintain recreational, pastoral, and historical elements of the natural river scene, while maintaining free-flowing non-polluted rivers.

Ozark National Scenic Riverways contains 134 miles of the free-flowing Jacks Fork and Current Rivers, numerous tributaries, and hundreds of springs, including five springs that have an average flow exceeding 100 cubic feet per second. The Ozarks Plateaus is one of the largest karst areas in the nation, and the Current River and its associated springs represent a world-class karst river system. The aquatic communities at ONSR are diverse and reflect the wide range of aquatic habitat available there. For example, the rivers, streams, and springs contain a mix of big-river, lowland, and upland fish species that represent 41% (112) of all the species (270) recorded in the entire Mississippi River drainage basin.

Both parks are designed as river corridors and much of the basin that contributes water and sediment to the mainstem channels is outside park boundaries. At Buffalo National River for example, only 11% of the watershed area is within the park boundary, while 29% is held by state and federal agencies, and the remaining 60% is privately owned. Conversion of forest to pasture is occurring at an average annual rate of approximately 3,600 acres per year amd is resulting in significant deforestation through time. In fact, since Buffalo National River's establishment in 1972, more of the watershed has been deforested (100,800 acres) than is protected within the boundaries of the National River (95,730 acres). Land-use in ARMO basins includes timber management (including recent controversial clear-cuts to supply chip mills), landfills, grazing, swine and poultry operations, urbanization, gravel mining, stream channelization, removal of riparian vegetation, and past, ongoing, and proposed lead-zinc mining operations.

The impact of land-use change on water-quality and sediment load is an ongoing concern for park management. Water-quality monitoring at BUFF (Mott, 1997; U.S. Department of Agriculture, 1995) has shown a correlation between agricultural non-point source chemical pollution (nitrates, for example) and stream water-quality. Portions of both the Buffalo River and the Jacks Fork River have been designated by State agencies as impaired because of non-point pollution (Arkansas Department of Pollution Control and Ecology, 1992; Missouri Department of Natural Resources, 1998). In 1995, the Natural Resources Conservation Service implemented a watershed protection/water-quality improvement project in the middle portion of the Buffalo River watershed to address documented water-quality degradation associated with land-use impacts.

Current and forecast land use practices will increasingly affect water-quality and aquatic habitat within ARMO parks, with some streams draining agricultural or urban landscapes already measurably impaired (Mott, 1997, Mott et al., 1999). Agricultural development and forest clearing has increased nonpoint source pollution, which represents the most significant long-term threat to BUFF. NPS water monitoring indicates agricultural sections of the river have higher nutrient, bacteria, and turbidity than sites on less disturbed sections (Mott, 1991). Fecal coliform concentrations exceeding 40,000 colonies per 100 milliliters of sample (col/100 mL) have been observed in three tributaries, and counts as high as 22,000 col/100 mL have been recorded in the Buffalo River (Steele and Mott, 1998; Porter et. al., 1999), as compared to the state standard of 200 col/100 mL. These and other environmental factors related to land use appear to be influencing macroinvertebrate and fish communities in the Ozark Plateaus.

Some ARMO parks are within mineralized belts that have been extensively mined. Leachate of heavy metals from mine tailings, areas of natural occurring metals, and possibly from copper-chromium-arsenic wood treatment facilities, have caused EPA freshwater criteria for copper, cadmium, lead, and zinc to be exceeded on a number of occasions at Buffalo National River (NPS, 1997). At Ozark National Scenic Riverways, a proposed mining development in the recharge area of Big Springs has drawn national attention because of the sensitive nature of the karst aquifer which feeds this and other world renowned springs in the area.

Other than during times of precipitation generated runoff, streams in the ARMO parks are recharged by groundwater. In karst terrain (an area underlain by soluble bedrock and characterized by caves, sinkholes, springs, and losing streams) groundwater contamination is a special concern due to the rapid nature of recharge and transport of contaminants through underground drainage networks. For example, water-quality studies at Buffalo National River showed Mill Creek contributes 96% of the nitrate load in the Buffalo River below their confluence. After many years of investigation, the source of the nitrates was linked to interbasin transfer of ground water from a more intensively developed agricultural basin to the north. Geologic mapping illustrated that spring discharge was localized at the base of the Mississippian limestone aquifer near the intersection of two previously undetected faults (Hudson, 1998). In one case, dye introduced into a sinkhole filled with cattle carcasses moved over two miles from the Crooked Creek basin to the Dogpatch Springs at the head of Mill Creek in less than five days. This rapid ground water transport can only be accomplished through conduit flow; conduit flow does not allow for filtration of pollutants.

Personnel with the United States Geological Survey (USGS) performed biological surveys in association with the National Water Quality Assessment Program (NAWQA) at almost 50 sites within the Ozark Plateaus, including six sites within Buffalo National River, ____ sites at Ozark National Scenic Riverways, and ___ sites in the other units. Petersen (1998) noted that land-use differences (forest vs. pasture) affect the relative abundance of several fish taxa nonuniformly. In particular, Petersen noted a greater relative abundance of herbivorous stonerollers, and a decline in bass and perch, in agricultural basins. Similar studies focused on benthic macroinvertebrates within the Buffalo River showed a statistically significant negative correlation between nitrates and species diversity (Bryant and Mathis, 1997).

In conjunction with these issues related to water-quality, there is also concern that land-use changes have increased the erosion in tributary basins and the amount of sediment and storm runoff delivered to the parks' mainstem channels. On the Buffalo River, increased soil erosion and changes in channel morphology through time have been correlated with increased land clearing of steep uplands within a tributary basin (Stephenson and Mott, 1992) and to the growth of road networks. Increased bank erosion rates in the Missouri Ozarks have also been correlated with historical riparian land clearing (Jacobson and Primm, 1997). Increased sediment yield is an important consideration for main-stem channels within the parks because they may lead to habitat degradation by changing channel morphology, bed material composition, and the frequency and magnitude of erosion and deposition events, thus altering biotic communities.

Studies that focused on the dynamics between nutrients and biotic communities in Ozark streams suggest that nutrient concentrations are not directly toxic to individual organisms. Rather, nutrients drive eutrophication processes and stimulate autotrophic communities that form the base of the food chain for much of the fish and macroinvertebrate communities. USGS-NAWQA studies in the Ozarks found the increased nutrient concentrations and less shaded conditions at agricultural reaches probably result in increased periphyton production, and therefore, a more abundant food source for herbivores (Petersen, 1998). Ongoing analysis of periphyton, water-quality, and habitat data indicate increases in periphyton biovolume and shifts in taxonomic composition at agricultural reaches compared to forest reaches. In other regional investigations, environmental factors such as substrate size, embeddedness, canopy angle, drainage area, gradient, and basic water chemistry also affected community composition at a given site. However, increased nutrient concentration exhibited the most consistent change in biologic communities in both site comparison and before and after studies (Smart et. al., 1985; Stewart, 1987; Arkansas Department of Pollution Control and Ecology, 1995).

Fish communities have also been altered by direct hydrologic modification of regional waterways. For example, the construction of Bull Shoals Dam on the White River 27 miles above its confluence with the Buffalo in the 1950s resulted in at least two major shifts in the Buffalo River's fish communities (Cashner and Brown, 1977; Horton and Johnson, 1993; Siegworth and Johnson, 1992). First, the cold-water tailrace below the Bull Shoals dam is stocked with rainbow and other trout species. Exotic rainbow trout have been observed in the Buffalo River as much as 60 miles upstream from the confluence. Second, the cold-water tailrace has altered the migration patterns of warm-water fish species that historically moved into the Buffalo River from the larger Mississippi River drainage. The thermal barrier has effectively extirpated the once prominent channel and flathead catfishes, and AGFC fisheries biologists believe white and black bass as well as white crappie have been similarly affected. Declines in these species went largely unnoticed until angler outcry resulted in a cooperative sport fisheries investigation between the National Park Service and the Arkansas Game and Fish Commission, which verified the fishing public's concerns (Horton and Johnson, 1993; Siegworth and Johnson, 1992). BUFF is also involved with an ongoing Environmental Assessment being conducted by the U.S. Army Corps of Engineers concerning a proposed municipal impoundment on a major tributary to the Buffalo River. **Need one para. Like the above for each of the individual units.**

Approach – General

The purpose of the proceeding discussion was to provide a clear statement of the need for an aquatic monitoring program and to point out: 1.) the vulnerability of aquatic resources to external threats and to highlight some ongoing impacts, 2.) the integrated nature of watershed land-use, aquatic habitats, water-quality, and biological communities, 3.) the importance of monitoring physical, chemical, and biological components of aquatic systems, and 4.) the need to be able to communicate monitoring results and trends to not only park managers, but to decision-makers and the public on a local, state, and national scale. Only with accurate facts and recognized expertise can the National Park Service hope to affect change and maintain the integrity of the aquatic ecosystems within the ARMO parks.

The Heartland Working Group formally recognized the high priority need to monitor aquatic resources within the ARMO parks under a concept they termed "River Integrity." The Work Group's concerns and objectives relative to aquatic resources can be lumped into the three broad categories shown in Table 1 that they felt were top priority monitoring items. More detailed discussions and objectives concerning each aquatic monitoring element are presented in the following section.

Within these three categories, the Working Group specifically pointed out the need for long-term information management, monitoring of aquatic dependent threatened and endangered species, and the need to incorporate springs into the monitoring program. To accomplish these aquatic resource monitoring objectives, the ARMO parks are to receive $405,404 per year, starting in FY2001. This money would be utilized as described in Table 2. The sampling scheme will employ a combination of routine long-term sampling, rotated intensive sampling, and short duration synoptic assessments as explained in the schedule section. Biological monitoring will be done in a rotating site manner, with key communities being targeted for a specific interval of years at specific sites.

Table 1: Concerns and objectives related to high priority monitoring categories recognized by the Heartland Network Inventory and Monitoring Working Group.

Monitoring Category	Concerns and Objectives
Land-use	*Concern* – Water-quality and biological studies have shown a clear relationship between increasing watershed development, higher pollution, and less diverse aquatic communities. *Objective* – Monitor land-use changes as a basis for interpreting the results of physical, chemical, and biological monitoring and to define temporal trends. Land-use analyses will be done at the watershed scale (where practical) and be categorized as forest, pasture, crop, urban, barren, transportation, and water.
Abiotic	*Concern* - Physical processes define and maintain the aquatic habitats upon which aquatic communities have evolved and are maintained. Changes in physical habitats can cause large-scale and potentially irreversible impacts to aquatic communities. *Objective* – Monitor critical indicators of water quality, flow, and geomorphic processes and parameters that effectively define the status and trends of aquatic habitat conditions.
Biotic	*Concern* – Biological communities must be monitored directly because it is not possible to measure everything that might affect living systems. Aquatic organisms are subject to and reflect cumulative impacts that can not otherwise be assessed through traditional water-quality monitoring. Also, visitors and administrators can directly appreciate the loss of biological integrity. *Objective* – Assess primary aquatic communities at a level of scrutiny sufficient to detect changes and quantify trends in aquatic ecosystems.

Table 2: Heartland Network Aquatic Resource Monitoring Element Descriptions and Budget.

	Distribution of Incoming Funds*		**Matching and Supporting Funds**		
Monitoring Element ONSR = Ozark National Scenic Riverways; BUFF = Buffalo National River; ARMO = Six Heartland Network Parks within Arkansas and Missouri; ADEQ = Arkansas Department of Environmental Quality; WRD = NPS Water Resources Division.	**ONSR**	**BUFF & Satellite parks**	**Heartland Network and WRD**	**Overhead, admin, & supervision (BUFF&ONSR)**	**Lab Analyses (ADEQ)**
1. Water-quality Monitoring – Staff a hydrologist at ONSR (GS 9/11) to supervise and conduct a water-quality monitoring program there. BUFF's current hydrologist will coordinate the overall ARMO monitoring program and directly supervise monitoring at BUFF and the ARMO satellite parks. Staff a hydrologic technician at BUFF (GS7/9) and a seasonal hydrologic technician at ONSR (GS5) to assist with field and laboratory work at each park, and a seasonal hydrologic technician at BUFF (GS5) to assist with data collection from the other four parks in the ARMO network. Budget includes money for supplies, meters, travel, vehicles, and analytical contracts. Staff time will also be devoted to other items as stated below.	90	75		15	18
2. Physical Habitat Assessments – The hydrologists at BUFF and ONSR, along with their field staff, install and monitor long-term physical habitat assessment reaches. BUFF team also establishes and monitors habitat assessment sites in ARMO satellite parks. Costs in this category include supplies, materials, and travel.	4	14		5	
3. Discharge and Hydrographs – Instantaneous discharge measurements will be recorded during all water-quality sampling to allow determination of loads. Intensive sampling sites will also be installed and monitored in each of the ARMO parks on a rotating basis, with BUFF and ONSR always having at least one continuous recording stream gauge in operation at all times. These gauges will be operated and maintained by the U.S. Geological Survey.	10	20		3	
4. Coordination and Information Management – A Program Coordinator and Data Management Specialist will be funded by the Heartland Network to oversee implementation and manage land-use and other GIS information for the entire network. NPS-WRD will also coordinate water quality related data management and nation-wide reporting requirements.			65	5	
5. Biological Monitoring – An aquatic ecologist (GS9/11) will be stationed at BUFF to coordinate a biological monitoring component for all parks. Seasonal biological technicians will be assigned to BUFF (GS5) and ONSR (GS5) to assist with the field components of the biological monitoring. This team, with assistance from the hydrologic technicians mentioned in Element 1, will be responsible for the biological monitoring needs of the ARMO Network.	15	83		10	
6. Special projects and contingencies – Discretionary money to be used for leveraging with external funding sources to conduct special studies that more effectively meet monitoring goals 4 and 5 stated previously in the detailed monitoring plan. Funds will also cover the cost of contingencies that might arise in a given year (such as meter replacement).	7	12			
Total Costs	126	204	65	38	18
Grand Total	**330,000**		**121,000**		

* $255,000 of the incoming funds are being provided by the NPS Monitoring Program as allocated to and prioritized within the Heartland Network. $75,000 is being provided by the Water Resources Division through a special allocation to support water quality monitoring efforts in the network.

Approach – Specific

This section is presented in a detailed, monitoring element by monitoring element, format. Attempts will be made whenever possible to show how each of the elements are linked and how the generated data will be managed and reported. As alluded to previously, water-quality monitoring relative to the ARMO network can be broken into three logistical categories: 1.) Monitoring at Ozark National Scenic Riverways by staff based at ONSR, 2.) Monitoring at Buffalo National River by staff based at BUFF, and 3.) Monitoring at the ARMO satellite parks (HOSP, PERI, GWCA, and ARPO) by staff based at BUFF. The following discussion provides the details related to how the monitoring program will be carried out relative to each of the three functional categories.

Element 1: Water-quality Monitoring

Buffalo National River has been administering and conducting a water-quality monitoring program for over 15 years (Mott, 1991; Mott, 1997). Water-quality monitoring has been very successful and has provided data to address numerous water resource issues (proposed landfills, proposed confined hog operations, proposed dams, and external land use issues, among others). The Water-quality Monitoring Plan (Malcolm et al., 1986; Mott, 1991) that guides this program was originally developed by the National Park Service's Water Resources Division, Ouachita Baptist University, and staff at Buffalo National River. Water-quality monitoring is supervised by Buffalo National River's hydrologist, coordinated closely with the Arkansas Department of Environmental Quality (ADEQ) (who perform the bulk of the laboratory analyses), and linked to numerous special studies. Developed by water-quality experts and tested and modified over years of field application, Buffalo National River's Water Quality Monitoring Program provides an excellent example for this expanded ARMO monitoring network.

The water-quality monitoring program at BUFF includes 9 sites on the mainstem river, 20 major tributaries and three springs (Table 4). Over 60 percent of the water flowing into the Buffalo River is monitored as part of this program, and over 50,000 individual readings have been recorded. The sampling schedule has been modified over time, diminishing from monthly to seasonal sampling as the database has expanded and statistically significant data populations have become available for each of the 32 monitoring stations. Realistic water-quality monitoring should follow this format, at first being intense to rapidly characterize each site, then diminishing to a level that can cost effectively detect changes and trends. At BUFF, NPS personnel collect water-quality samples, take field readings, perform fecal coliform bacteria and turbidity analyses, manage an excel database, and complete a comprehensive summary report every five years. ADEQ personnel assist by performing the more complex laboratory analyses (nutrients, ions, and metals) at their EPA certified water-quality lab, and permanently store all of the data on the EPA's nationwide STORET database. ADEQ has offered to extend this service to the 3 other park's in this monitoring network that lie within Arkansas, saving significant analytical costs.

Past water-quality monitoring at Ozark National Scenic Riverways has focused on 16 main-stem sites located above and below major river accesses. Most routine sampling has taken place during the summer season when visitation is highest. The U.S. Geological Survey has conducted additional sampling at approximately 10 sites. Some monitoring has also been conducted at four of the park's largest springs. Two intensive U.S. Geological Survey NAWQA fixed station are also located within the park; one on the Current River at Van Buren, and one on the Jacks Fork River at Eminence. Water-quality measurements have been collected at approximately 47 additional locations within the park, but these were mostly one-time sampling efforts (National Park Service, 1995). Past water-quality monitoring sites will be utilized in the ARMO monitoring program wherever they meet the following criteria. Use of pre-existing sites will allow utilization of pre-existing data and thus increase the rate at which the initial objectives of the monitoring program can be achieved. Additionally, the frequency at which sites need to be monitored can also be adjusted relative to the amount of pre-existing data.

Objectives

The objectives of the water-quality monitoring element are:

1.) To provide a comprehensive baseline data-set of water-quality (concentrations and loads) for the streams and springs within the ARMO network.

2.) To obtain sufficient spatial and temporal coverage from representative sampling sites in the ARMO parks to measure natural variation, monitor both short and long-term water-quality trends, and determine impacts related to land-use, recreation, development, or other sources.

3.) Assure compliance with federal and state water-quality standards applicable on a site-specific basis to the ARMO parks.

4.) Present management concise summaries of water-quality conditions and potential measures to improve water-quality in problem areas both inside and external to park boundaries and evaluate the effectiveness of water-quality improvement efforts.

Criteria for establishing water-quality monitoring sites

Water-quality monitoring locations within each of the ARMO parks are selected using the following criteria:

A.) Main-stem rivers (specific to BUFF and ONSR). These include the Buffalo River at BUFF, and the Current and Jacks Fork rivers at ONSR.

  1.) Sampling sites should be spaced at approximately equal distance from headwaters to the point at which the rivers exit the park.

  2.) Sampling sites should be located as far below major confluencing tributaries as possible, or directly above major confluencing tributaries, to avoid problems associated with partially mixed waters.

  3.) Site access must be reasonable, either accessible by vehicle, boat, or within walking distance.

4.) Sampling sites will be located at riffles to insure mixing.

B.) Tributaries to main-stem rivers (specific to BUFF and ONSR)

1.) Sampling site density shall include monitoring of all major tributaries and the majority of water flowing into the main-stem rivers from throughout the watershed.

2.) Sampling sites should be located a reasonable distance above the confluence with the main-stem river so that backwater conditions will be avoided during high-flow conditions.

3.) Site access must be reasonable, either accessible by vehicle, boat, or within walking distance.

4.) Sampling sites will be located at riffles to insure mixing.

C.) Stream Reach (pertains to PERI, HOSP, GWCA, and ARPO)

1.) Sampling sites should be located as close to the upstream park boundary as possible.

2.) Sampling locations should be adjusted downstream from the park boundary to provide for adequate mixing of tributaries or point sources.

3.) If a discharge or major recreational activity is located within the park, a second monitoring site should be located at the lower end of the within-park stream reach.

4.) Site access must be reasonable, either accessible by vehicle, boat, or within walking distance.

5.) Sampling sites will be located at riffles to insure mixing.

D.) Springs (applicable to all units except HOSP and ARPO)

1.) All relatively large springs contributing at least 10 percent of the base-flow to the main-stem rivers should be monitored. Large springs should be considered as tributaries relative to the need to monitor the majority of the water coming into the river from throughout the basin (see B1 above).

2.) Some smaller springs are also relatively important to units that have only small springs, or where springs are associated with rare or endangered species, and will also be monitored.

3.) Sampling sites will be located in the first riffle formed below the spring.

4.) Site access must be reasonable, either accessible by vehicle, boat, or within walking distance.

E.) Hot springs

1.) Hot springs are located within Hot Springs National Park only. These springs are highly modified, buried, and part of an elaborate plumbing system that once provided water to a series of bathhouses. The springs retain almost no natural characteristics at the surface, yet they still contain potentially important nano-fauna. Samples should be collected from the point of public consumption.

2.) Samples should also be collected during periods of significant rainfall to assess infiltration of surface contamination from urbanized areas. These samples will be collected as near the individual sources as possible.

Tables 3, 4, and 5 present relative information for each of the water quality monitoring sites in the ARMO network. The maps presented in Figures _ through _ show the location of water quality monitoring sites within each of the ARMO units. At Ozark National Scenic Riverways, the monitoring network includes __ sites on the main-stem of the Current River, __ sites on the main-stem of the Jacks Fork River, __ sites on surface tributaries, and __ springs. ___ sites have pre-existing water-quality information sufficient to characterize the ambient conditions at these sites. At the remaining __ sites, ___ sites have some water-quality data associated with them and ___ sites have no water-quality data. The timing of sample collection from each site will vary as a function of the level of pre-existing data as shown in Table 3.

At BUFF, the monitoring network incudes 9 sites on the main-stem of the Buffalo River, 20 sites on tributaries, and 3 springs. All of these sites have sufficient water-quality information to characterize the ambient conditions at the sites.

Similar discourse as in the above para for satellite units.

Table 3: Relative Information for Water-quality Monitoring Sites at Ozark National Scenic Riverways.

Main-stem Sites on the Current River					
Site Name	**Site Code**	**Watershed Area(mi^2)**	**% of total Watershed**	**Pre-existing WQ Data**	**Stage or Flow Gauge**
Main-stem sites on the Current River					
Tan Vat	OZAR0094	73	4		
Cedargrove	OZAR0092	147	8		NPS staff
Akers –Upper	OZAR0088	381	21		NPS staff
Pulltite – Access	OZAR0076	418	23		NPS staff
above Sinking Cr	OZAR0130	716	39		NPS Wire Wt
above Two Rivers	OZAR0131	1273	70		NPS staff
Powder Mill Access	OZAR0030	1342	74		NPS Wire Wt
Watercress Access	OZAR0017	1529	84		USGS DCP
Cataract Landing	OZAR0124	1770	98		
Hawes Campground	OZAR0125	1814	100		
Main-stem Sites on the Jacks Fork River					
Buck Hollow	OZAR0098	182	10		USGS DCP
Rymers	OZAR0113	239	13		
Bay Creek	OZAR0082	293	16		
Below 106 bridge	OZAR0066	303	17		USGS DCP
Eminence	OZAR0047	349	19		USGS DCP
Two Rivers	OZAR0034	444	24		
Tributary Monitoring Sites – Current River					
Big Creek	OZAR0121	129	7		
Gladden Creek	OZAR0126	66	4		
Sinking Creek	OZAR0062	126	7		
Rogers Creek	OZAR0021	19	1		
Pike Creek	OZAR0018	140	8		
Tributary Monitoring Sites – Jacks Fork River					
North Prong	OZAR0110	59	3		
South Prong	OZAR0111	88	5		
Jam Up Creek	OZAR0128	21	1		
Bay Creek	OZAR0083	15	1		
Mahans Creek	OZAR0050	54	3		
Shawnee Creek	OZAR0038	20	1		
Spring Monitoring Sites – Current River					
Welch Spring	OZAR0090	121	7		
Pulltite Spring	OZAR0080	161	9		
Round Spring	OZAR0057	45	2		
Blue Spring (Current River)	OZAR0025	107	6		
Big Spring	OZAR0012	967	53		NPS staff/datalogger
Spring Monitoring Sites – Jacks Fork River					
Blue Spring	OZAR0022	24	1		
Aley Spring	OZAR0068	125	7		NPS staff

Notes

Spring recharge areas shown here include areas drained outside the surface watershed

Discharge is measured only at USGS DCP sites (excluding JF @ Buck Hollow)

Approxamate areas derived from 8 digit hydro unit GIS theme

Table 4: Relative Information for Water-quality Monitoring Sites at Buffalo National River

Site Name	Site Code	Watershed Area (mi^2)	% of total Watershed	Pre-existing WQ Data	Stage or Flow Gauge
Main-stem Sites on the Buffalo River					
Wilderness Boundary	R-1	51	4.0	100%	Flow, USGS
Ponca	R-2	108	8.2	100%	Stage, NPS
Pruitt	R-3	176	13.3	100%	Stage, NPS
Hasty	R-4	345	26.1	100%	
Woolum	R-5	544	41.1	100%	
Gilbert	R-6	829	62.6	100%	Flow, USGS
Highway 14	R-7	1047	79.1	100%	Stage, NPS
Rush	R-8	1070	80.8	100%	
Mouth	R-9	1323	100.0	100%	
Tributaries					
Beech Creek	T-1	18.8	1.4	100%	
Ponca Creek	T-2	4.2	0.3	100%	
Cecil Creek	T-3	19.9	1.5	100%	
Mill Creek (upper)	T-4	19.4	1.45	100%	
Little Buffalo River	T-5	128.1	9.7	100%	
Big Creek (upper)	T-6	83.5	6.3	100%	
Davis Creek	T-7	26.2	2.0	100%	
Cave Creek	T-8	47.5	3.6	100%	
Richland Creek	T-9	125.7	9.0	100%	Flow, USGS
Calf Creek	T-10	47.4	3.4	100%	
Mill Creek (middle)	T-11	15.2	1.1	100%	
Bear Creek	T-12	88.4	6.3	100%	Flow, USGS
Brush Creek	T-13	18.0	1.4	100%	
Tomahawk Creek	T-14	33.3	2.5	100%	
Water Creek	T-15	35.5	2.7	100%	
Rush Creek	T-16	14.9	1.1	100%	
Clabber Creek	T-17	24.4	1.8	100%	
Big Creek (lower)	T-18	124.6	9.4	100%	
Middle Creek	T-19	9.8	0.7	100%	
Leatherwood Creek	T-20	12.2	0.9	100%	
Spring Monitoring Sites					
Luallen Spring	S-1	Unknown	unknown	100%	
Mitch Hill Spring	S-2	20.8	2.4	100%	
Gilbert Spring	S-3	Unknown	unknown	100%	

Table 5: Relative Information for Water-quality Monitoring Sites at ARMO Satellite Parks

George Washington Carver National Monument					
Site Name	**Site Code**	**Watershed Area**	**% of total Watershed**	**Pre-existing WQ Data**	**Stage or Flow Gauge**
Pea Ridge National Military Park					
Arkansas Post National Historic Site					
Hot Springs National Park					

Parameters

The water-quality parameters to be collected as part of the ARMO water-quality monitoring element are shown in Table 6. Some of these parameters will be analyzed in the field by hydrologic technicians utilizing NPS meters and standard USGS sampling procedures (Wilde and Radtke, 1998). Field parameters include water temperature, pH, specific conductance, and dissolved oxygen (both concentration and percent saturation). Discharge measurements will be made using a current meter following methods described by Buchanan and Sommers (1984) to allow instantaneous load calculations and annual load estimates at each site. Spatial location of sampling sites and other important features will be identified using GPS instrumentation.

Table 6. List of water-quality parameters to be analyzed as part of the ARMO monitoring. [MRL = minimum reportable level, mg/L = milligrams per liter, μg/L = micrograms per liter, μS/cm = microsiemens per centimeter, CFU/100ml = colony forming units per 100 milliliters]

CONSTITUENT	MRL	UNIT	CONSTITUENT	MRL	UNIT
FIELD PARAMETERS					
PH	NA	NA	Temperature	0.5	^{O}C
Specific Conductance	1	μS/cm	Dissolved Oxygen	1	mg/L
FECAL INDICATOR BACTERIA					
Fecal coliform	0	CFU/ 100ml			
NUTRIENTS					
Phosphorus, total	0.02	mg/L	Nitrogen, nitrite + nitrate, dissolved	0.01	mg/L
Phosphorus, orthophosphate, dissolved	0.005	mg/L	Nitrogen, ammonia + organic, total	0.05	mg/L
Nitrogen, ammonia, dissolved	0.005	mg/L	Nitrogen, nitrite, dissolved	0.01	mg/L
COMMON CONSTITUENTS (Dissolved)					
Chloride	0.07	mg/L	Copper	0.5	μg/L
Sulfate	0.04	mg/L	Iron	15	μg/L
Fluoride	0.009	mg/L	Lead	0.3	μg/L
Total dissolved solids	1.0	mg/L	Magnesium	0.13	mg/L
Aluminum	127	μg/L	Manganese	0.5	μg/L
Arsenic	1.0	μg/L	Nickel	2.0	μg/L
Barium	8.8	μg/L	Potassium	0.46	mg/L
Beryllium	0.11	μg/L	Selenium	3.0	μg/L
Boron	4.5	μg/L	Sodium	0.12	mg/L
Cadmium	0.14	μg/L	Vanadium	1.0	μg/L
Calcium	0.05	mg/L	Zinc	1.0	μg/L
Chromium	0.4	μg/L	Silica	1.0	mg/L
Cobalt	0.5	μg/L			
Total organic carbon	1.0	mg/L	Turbidity	0.1	NTU

In the Arkansas parks, all laboratory parameters will be analyzed at the Arkansas Department of Environmental Quality's EPA certified State Water-quality Laboratory, except for fecal indicator bacteria which will be analyzed in the field or at BUFF's lab to comply with limited holding time. In the Missouri parks, water analyses will be contracted with an approved laboratory or performed in the field if appropriate for recommended holding times.

Data Management

Standardized field forms will be utilized to collect pertinent information at the time of collection. This includes the site name and number, time, date, air temperature, 24-hour rainfall, sampler's name, hydrograph status (base-flow, rising, falling), staff gauge reading, laboratory name where samples will be shipped, comments, and the actual field readings. Field forms will be filed in a temporary filing system until such time as the laboratory results are returned. Once all the results are compiled for an individual station, these data will be entered into a park-based Excel spreadsheet database, with hard copies stored separately. The hydrologist at Ozark National Scenic Riverways will be responsible for in-house data management at ONSR. The hydrologist at Buffalo National River will be responsible for data management relative to the other five units in the ARMO network. For Arkansas parks, the Arkansas Department of Environmental Quality will upload all data into the EPA's STORET database as a permanent backup and a universally accessible database. For Missouri parks, Buffalo National River staff will accomplish the STORET upload with assistance from data management personnel at the NPS Water Resources Division.

Data Reporting

An annual report summarizing the findings of the previous year will be prepared for each of the smaller satellite units for each of the first five years. At the end of the first five years, a comprehensive and detailed statistical analysis of the water-quality findings will be prepared following the format used in previous reports for Buffalo National River (i.e. Mott, 1997) for all parks within the ARMO network. After the first five years comprehensive reports will be completed on five-year increments. Reports will include an executive summary, narrative, graphical, and statistical presentations and data summaries, a section presenting conclusions, and recommendations for management. The reports will focus on: 1.) comparisons between sites, 2.) correlations between data results and land-use in the upstream watershed, 3.) trends over time, 4.) relative departure from background sampling sites, 5.) influence of runoff on maximum concentrations, 6.) seasonal patterns, 7.) comparison to applicable water-quality standards (including public health criteria), and 8.) statistical significance where applicable.

Element 2: Physical Habitat Monitoring

Physical habitat monitoring is the repeated measurement of quantifiable geomorphic attributes through time, such that changes can be detected and their relationship to physical processes and biological communities inferred. The U.S. Forest Service has assimilated field measurement techniques developed by U.S. Geological Survey personnel, Rosgen and associates, and others and developed a monitoring guide entitled "*Stream Channel Reference Sites: An Illustrated Guide to Field Techniques* (Harrelson et al., 1994). The tools, techniques, and data collection outlined in this manual provide the basic guidelines for the ARMO physical habitat monitoring. Jacobson et. al. (1998) developed and are implementing an effort they have entitled *Tributary Land-use and Aquatic Habitat Quality at Buffalo National River and Ozark National Scenic Riverways*. This work has already collected baseline measurements of many of the geomorphic attributes to be measured and monitored at 19 tributary reaches at Buffalo River and 20 tributary reaches at Ozark National Scenic Riverways. Other work by Jacobson and his associates and the USGS NAWQA Program will be used as the basis for establishing geomorphic monitoring reaches on the main-stem rivers. Previous geomorphic assessments have not been done at the satellite parks.

Watersheds feeding the ARMO parks have undergone significant land-use changes in recent decades, changes that have been linked to increased sediment yields. Elevated tributary sediment yields can degrade aquatic habitat by decreasing pool area, changing stream-bed sediment composition, and increasing the rate and frequency of changes in stream-bed morphology. These physical alterations degrade habitat quality and biotic communities within park streams allowing species more tolerant to the post-alteration environment to dominate. The most direct measure of sediment yield involves monitoring of bed and suspended load transport. Calculations of loads generally requires a sediment-load rating curve and a discharge-rated stream gage. The costs of such instrumentation are prohibitive for extensive evaluations. In this monitoring program, proven techniques will be employed to consistently measure the potential impacts of changes in water and sediment budgets on habitat quality.

In evaluating a link between sediment supply and channel disturbance, it is also important to recognize that many other factors may control stream morphology. Channel cross section monitoring (McKenney and Jacobson, 1996, McKenney, 1997) and aerial photo interpretation (Jacobson and Pugh**,** in press) show that some river reaches within the Ozarks have had relatively stable planform geometries for decades while others have undergone dramatic bar and bank migration. In some cases, the distribution of these reaches has been linked to controlling factors that are independent of changes in sediment supply. For example, stream segments flowing along bedrock walls tend to maintain stable geometries. This contrasts with segments where the channel collides with the valley wall or flows across the valley bottom where the channel may show rapid lateral migration, channel avulsion, and the formation of large, unvegetated gravel bars (Miller and Jacobson, 1995; Jacobson and Pugh, in press). Bedrock lithology, riparian vegetation along the mainstem channel, and the land-use history of the watershed may also be important factors that determine local channel morphology (Jacobson and Gran, in press). Habitat degradation resulting from a tributary disturbance may be either mitigated or exacerbated by local channel and valley morphology. The monitoring sites chosen will integrate all such factors and give managers a holistic framework in which habitat alterations can be comprehended and addressed.

Geomorphic processes may take decades or even lifetimes to produce measurable and consistent, sometimes irreversible alterations to aquatic habitats. Therefore, establishing permanent benchmark reference sites and reaches is the first step in the long-term monitoring process. Follow-up monitoring at repeated intervals provides the technically correct and comparable data that can be used to track stream habitat change through time. The field-based survey of channel morphology and substrate composition will provide measures that can be explored for relations with land use above individual reaches. Because the field-based data will include measures of channel depths and substrate characteristics, they are expected to indicate chronic, low-level effects of land use in the tributaries. In particular, the field-based data are expected to resolve the effects of increased yields of fine sediment from agricultural development and coarse sediments from roads, drainage network extensions, and eroding streambanks.

Objectives

1.) Monitor channel morphology and substrate characteristics at stream reaches within the ARMO network. Utilize pre-existing study reaches where data exists and add to this database as appropriate to provide a comprehensive baseline data-set of geomorphic parameters.

2.) Obtain sufficient spatial and temporal coverage from representative sampling reaches in the ARMO parks to measure natural variation, monitor both short and long-term water-quality trends, and determine impacts related to land-use, recreation, development, or other activities.

3.) Integrate geomorphic information with land-use, water-quality and biologic monitoring results.

4.) Present management concise summaries of habitat conditions and potential measures to improve or restore habitat attributes in problem areas both inside and external to park boundaries, and evaluate the effectiveness of habitat restoration efforts at the reach or watershed scale.

Criteria for establishing geomorphic monitoring reaches

Geomorphic monitoring reaches within each of the ARMO parks are selected using the following criteria:

A.) Main-stem rivers (specific to BUFF and ONSR). These include the Buffalo River at BUFF, and the Current and Jacks Fork rivers at ONSR.

1.) Sampling reaches should be located at or near water-quality monitoring sites, spaced at approximately equal distance from headwaters to the point at which the rivers exit the park.

2.) Every effort will be made to utilize previously existing data and previously surveyed stream reaches. Adding only the minimum amount of measurements needed to complete the baseline data-set.

3.) Monitoring reaches should be in relatively non-disturbed reaches, with little anthropogenic disturbance in the channel or riparian zone, or otherwise directly influencing the reach.

4.) Sampling sites should be located in both bluff-controlled and alluvial banked reaches. Bluff-controlled and alluvial bank reaches should alternate down the river. Bluff-controlled habitats tend to be more stable and experience little lateral migration, while alluvial bank reaches are potentially more responsive to changes in sediment or flow regimes.

5.) The monitored reach should include an entire meander (i.e. two bends) if possible. The length should be at least 20 times the bankfull width of the channel.

6.) Reach access must be reasonable, either by vehicle, boat, or within walking distance.

B.) Tributaries to main-stem rivers (specific to BUFF and ONSR)

1.) All major tributaries are monitored and monitoring reaches should be located at or near water-quality monitoring sites.

2.) Monitoring reaches should be in relatively non-disturbed reaches, with little anthropogenic disturbance in the channel or riparian zone, or otherwise influencing the reach. These monitoring reaches have already been established in previous work.

3.) Sampling sites should be located a reasonable distance above the confluence with the main-stem river so that backwater effects will be avoided.

4.) The monitored reach should include an entire meander (i.e. two bends) if possible. The length should be at least 20 times the bankfull width of the channel.

5.) Site access must be reasonable, either accessible by vehicle, boat, or within walking distance.

C.) Stream Reach (pertains to PERI, HOSP, GWCA, and ARPO)

1.) Sampling reaches should be located at or near water-quality monitoring sites.

2.) Monitoring reaches should be relatively non-disturbed, with little anthropogenic disturbance in the channel or riparian zone, or otherwise influencing the reach, wherever possible.

3.) Sampling reaches should be located where backwater effects will be avoided.

4.) Physical measurements will take place along a pool-riffle-pool-riffle sequence and the monitored reach should include an entire meander (i.e. two bends) if possible. The length should be at least 20 times the bankfull width of the channel.

5.) Site access must be reasonable, either accessible by vehicle, boat, or within walking distance.

Geomorphic Parameters

Longitudinal Profiles - A total station, modified two-prism surveying rod, and data-logger, will be employed to survey longitudinal profiles covering the entire length of selected reaches. Longitudinal surveys establish the elevation of the existing water surface, channel bottom at the thalweg, bankfull stage, floodplains, and terraces. The optimum use of these data for habitat monitoring is to determine maximum pool depth and residual pool area, and thereby monitor reaches to detect aggradation or degradation, and concomitant change in habitat structure. Methodologies for completing longitudinal surveys are described in detail in Harrelson et. al., 1994.

Cross-sections - A total station, standard prism, and data-logger will be employed to survey channel cross-sections. Measurements of bankfull channel width, maximum and mean bankfull depths, and bankfull width/maximum depth ratios within glide and run habitats will be performed at permanently monumented cross-sections. Measurements will be made using the concept of topographic breaks. In other words, fixed interval distances will not be used as a criteria for placement of rod-points. Rather, where the slope of the bank changes, a channel feature rises above the stream bed, or where the deepest point of the thalweg is crossed, for example, a rod reading will be taken so that the maximum of variation is measured and displayed where it occurs along the cross-section. At least 20 readings are recommended to accurately portray most channels, with more needed for broad or structurally complex sites. Outside the channel, important features including the active floodplain, bankfull elevations, and stream terraces will be surveyed.

Selection criteria for permanent cross-sections include: 1.) a straight reach between two meander bends, 2.) clear indicators, or the ability to project indicators, of the bankfull discharge, 3.) presence of one or more terraces, 4.) channel section and form typical of the stream, and 5.) a reasonably clear view of geomorphic features. Marked endpoints for the cross-section will be placed well above and back from the banks and marked with coded surveyors benchmarks set in concrete to a depth of at least 18 inches. The locations of benchmarks will be recorded using GPS technology, and witness trees, step logs, site maps, and metal detectors will all be employed to recover benchmarks in the field when sites are revisited. Protocols for establishing monumented cross-sections are explained in detail in Harrelson et al., 1994. Four permanent cross-sections will be established on each tributary reach, and six cross-sections will be utilized on main-stem reaches.

Photomonitoring - Photomonitoring techniques will be used to visually monitor channel changes at cross-sections through time. A total of four digital photographs will be taken at each transect. Photographs will be taken at the elevation of the bank-full discharge on the left bank showing the cross-section and focused on the bank-full elevation of the right bank of the channel on the far side of the cross-section, and vice-versa. Two additional photographs will be taken perpendicular to the cross-section looking directly down and directly up the center of the channel from the mid-point of the cross section. The digital photos will be an effective way to demonstrate measured channel and habitat alterations over time to management and the public.

Substrate and Embeddedness - Substrate characteristics (size and distribution of sizes) are important determinants of habitat quality. Substrate characteristics will be measured using Wolman (1954) pebble count procedures (random measurements of clast size) at the monumented cross-sections. Protocols for collecting and analyzing substrate data are explained in detail in Harrelson et al., 1994.

Embeddedness measurements will be performed wherever cobble and/or gravel sized particles are present within the stream channel. Embeddedness in this document refers to the average ratio of the depth at which cobble/gravel is embedded in smaller materials versus the height of the exposed portion of the cobble above the stream bed. Measurements of embeddedness will be performed for all cobble in the vicinity of monumented cross-sections until all the cobble has been measured or 50 measurements have been made. For sites lacking cobble, the relationship between gravel and silt/sand will be used.

Bank Stability/Riparian Integrity - In the course of the longitudinal surveys, bank stability and percent vegetative coverage on banks will be recorded. Percent vegetative coverage is estimated by the rod person at each survey-shot location on both the right and left bank as the longitudinal survey proceeds. A subjective estimate of bank erosion (none, minor, significant, and major) will also be recorded for each bank at each longitudinal shot location. Field staff will be trained and site-specific manuals developed to aid in making consistent estimates of vegetative coverage and bank stability.

Canopy Angle - Canopy angle will be measured from the midpoint of the channel at each transect. The horizontal angle from the line of sight of the investigator to the tallest feature on the bank is summed and then subtracted from 180 degrees, resulting in the canopy angle. **Check the USGS habitat protocols on the web for better details. Need to find protocols for canopy cover.**

Data Management

Standardized field forms, tape-recorders, and automated data-logging techniques will be utilized in data collection. Surveying with a total station produces a large quantity of data in a short period of time, and automated data techniques must be employed to make the data collection operation efficient. Once a cross-section or longitudinal profile is completed, the data will be uploaded to a laptop computer, and graphical plots will be produced and examined thus allowing surveying errors to be detected and remeasurements performed if necessary. Pebble count data will be tape recorded (one person) or recorded on standard forms (two people) in the field for later entry into the database. Other readings will be recorded in specially designed field books for later entry into an Excel spreadsheet and/or GIS. The hydrologists at BUFF and ONSR will be responsible for these data collection efforts, with BUFF staff also monitoring reaches in the satellite parks. The GIS specialist at BUFF will input, append, manage, and back-up both the data and the metadata files related to habitat monitoring for the entire ARMO network.

Data Reporting

Geomorphic monitoring will be conducted less frequently than water-quality monitoring as presented later in the schedule table. Thus reports which analyze geomorphic trends and alterations and look for correlations with land-use will be produced only every fifth year, when the comprehensive water-resource document is produced. Major findings will be included in the report's executive summary, along with narrative, graphical, and statistical presentations and data summaries, a section that summarizes conclusions and findings, and recommendations for management. The habitat assessment will be structured so as to: 1.) compare reaches and transects, 2.) correlate results with land-use in the upstream watersheds, 3.) analyze trends over time, 4.) determine departure from background sites and standard curves developed for the physiographic area, and 5.) examine statistical significance where applicable.

Element 3: Discharge Measurement and Stream Gauging

Discharge measurements and hydrograph recording represent critical water-quality and water quantity monitoring tools. Flow measurement and recording will be accomplished in three ways: 1.) routine discharge measurements in conjunction with water-quality collections, 2.) continued operation of long-term gauging sites, and 3.) revolving location of limited duration continuos recording sites. Routine discharge measurements from sites and times when and where water-quality is measured allows calculation of instantaneous loads and estimates of average annual base-loads. Continuos gauges provide a long-term record of runoff and base-flow characteristics for basins. Limited duration gauging will be used in critical basins or stream reaches to integrate with high-flow water-quality data collection. Stream flow data will allow quantification of nonpoint source loading from tributary basins and within main-stem locations not currently served by a continuous recording gauge. Routine discharge measurements, data storage, and analysis will be performed by BUFF and ONSR staff, while gauging stations and the management of the data they produce will be managed by USGS personnel and systems.

There are currently __ stream-gauging stations in the ARMO network. Three of these gauges can be considered long-term. __ gauges were installed and operated under the USGS NAWQA program as shown in Table __.

Table 7: Relative information for stream gauging stations in the ARMO watersheds.

Gauge Name/ Location	Basin Area	Period of Record	Funding Agency(s)	Maximum Stage (ft) & Flow (cfs)	Average Annual Flow (cfs)	Minimum Flow (cfs)
Gauges within the Buffalo River Watershed						
Buffalo River near St. Joe, AR (about mid-way down the length of the river)	829 mi^2	1939-present	Arkansas Soil and Water Conservation Commission and U.S. Army Corps of Engineers	54' 158,000	1058	6 cfs (September, 1957)
Buffalo River above Boxley (near headwaters)	57mi^2	1993-1995, 1998 to current year	Arkansas Soil and Water Conservation Commission	11' 11,600	118	0.04
Richland Creek (major tributary to Buffalo River near Witts Springs, AR)	67.4 mi^2	1995 to current year	Arkansas Soil and Water Conservation Commission	11' 12,900	109	0.00
Bear Creek (major tributary to Buffalo River near Marshall, AR)	83.1 mi^2	1999 to current year	National Park Service	Insufficient data	Insufficient data	Insufficient data
Gauges within the Current River Watershed						
Current River near Van Buren, MO (about	1,667 mi2	1912 - current year	U.S. Army Corps of Engineers	27.39' 125,000	2001	473
Jacks Fork River at Alley Spring, MO	298 mi2	1993-present	USGS Global Change Research Program	15.9' 48,700	329	57
Jacks Fork River near Mountain View, MO (stage reporting only)	No Data	No Data	National Park Service	No Data NA	NA	NA
Jacks Fork River at Eminence, MO	398 mi2	1921 - present	USGS	17.82' 58,500	466	64

Objectives

The objectives vary depending on the method and application of the discharge measurement:

1.) Instantaneous Discharge - To quantify flow volumes that are used in conjunction with water-quality results to calculate instantaneous loads and estimate annual base-flow loads. Trends in these randomly collected discharge measurements can also be correlated with observations of changes in flow patterns at long-term gauges.

2.) Long-term Gauging Sites - To provide a continuous long-term hydrograph record from which deviations in runoff and base-flow characteristics can be quantified whether they result from basin-specific or global environmental change.

3.) Revolving Gauges - Establish temporary (two-year duration) gauges, with priority given to basins with the least amount of forest cover. High-flow (runoff) water-quality monitoring can then be used to calculate storm loads, which, in nonpoint source basins, can far exceed annual base-flow loads.

Criteria for establishing discharge and gauging sites

Instantaneous discharge measurements will be made at the same time and in the same vicinity as water-quality sampling following methods described by Buchanan and Sommerville (1984). Sites on the main-stem rivers will often be too large and/or deep to allow discharge calculation using standard wading techniques. When it is not practical to measure instantaneous discharge directly, it will be estimated using rating tables and staff gauges, where appropriate, or by using the watershed ratio method. The watershed ratio method uses the discharge reading from a measured or gauged site, and then multiplies that reading by the ratio of the watershed area at the site of undetermined discharge/watershed area at the measured site, to estimate the contribution of water from the portion of the basin between the two sites, and therefore the approximate discharge.

Long-term gauging stations have already been established and will hopefully continue to be funded by those entities currently providing funding for their operation (Table 7).

Short-term gauging stations will be located near water-quality monitoring sites, and will utilize bridges where one is proximal to allow direct high flow calibration measurements. There is only enough funding available to allow two temporary monitoring gauges to be operated by this monitoring program in the ARMO network at any given time. Watershed land-use, and management concerns will be used to prioritize gauge locations, with higher priority given to basins with more intensive land use/issues. There also exists the opportunity to utilize other gauges currently operating in the basins (see Table 7) for high-flow and other sampling activities.

Data Management

Instantaneous discharge readings will be calculated by recording cell-specific velocity and area information on field forms at the same time water-quality measurements are taken and recorded. Discharge is then calculated in the office using standard equations. Instantaneous discharge data are archived with the water-quality data and individual readings are treated as another numeric field in both the park-based Excel and EPA based STORET water-quality databases.

Both long-term and short-term stream gauging records will be stored and maintained by the U.S. Geological Survey as per their standard protocols. Metadata files concerning these activities will also be recorded by the BUFF-based GIS operator for future reference by National Park Service staff.

Data Reporting

The USGS will provide yearly summaries of stream gauge data to the NPS in their standard hardcopy and electronic formats. Both the gauge station and instantaneous discharge data will be used to calculate instantaneous loads and estimate base-flow and storm-flow loads in both the one year and five year reports mentioned earlier. The hydrologists at BUFF and ONSR will prepare these comprehensive water resource reports and will specifically address parameter load comparisons and patterns among tributaries and springs, and correlations between instantaneous, average base-flow, and storm-flow loads and watershed land-use. Trends will also be analyzed along with seasonal patterns and statistical significance where applicable.

Element 4: Land-Use and Information Management (GIS)

Previous efforts have resulted in the compilation of a Geographic Information System (GIS) based spatial-data framework for the BUFF and ONSR watersheds, and their tributary drainage basins. The GIS layers developed for the ARMO parks are shown in Table 8. However, there is currently a lack of GIS equipment and professional expertise in the GIS field within the ARMO network, and the majority of the satellite parks have a limited amount of GIS information developed for their areas of interest.

Table 8: GIS Data-layers available for the parks within the ARMO monitoring network.

GIS Data-layers	ARMO Network Parks					
	BUFF	ONSR	HOSP	GWCA	PERI	ARPO
Land Use	Yes	Yes				
Geology	Yes	Yes				
Soils	Yes	Yes				
Hydrography	Yes	Yes				
Roads	Yes	Yes				
Slope	Yes	Yes				
Digital Elevation Model	Yes	Yes				
Aspect	Yes	Yes				

Maybe put the scale of the coverage or the resolution in the column if the layer exists, parks could fill in this table individually.

A GIS will be established at Buffalo National River to serve as the ARMO network's primary water resource related data repository, analysis, and display tool. To properly equip a GIS, several basic data layers are required as indicated in Table 8, some data-layers need to be developed for the satellite parks. Most of these data layers are fixed with respect to time (geology, soils, slope, hydrography), however, land-use is constantly changing. Land-use mapping alone generates a tremendous amount of data, and to properly track, maintain, and integrate both the static and the dynamic databases will require specialized meta-data skills and professional staffing. Along with database management and analysis responsibilities for the entire ARMO network, the GIS operator will coordinate the acquisition of land-use and other data-layers as defined in the schedule section.

Land-use/land-cover maps will be developed for the ARMO parks through spectral analysis of Landsat Thematic Mapper imagery with a resolution of at least 30 meters or similar remote sensing technology. Land-use categories used will be agriculture, forest, water, urban/barren, transportation, power and communications. Accuracy of determination between forest and agriculture must meet or exceed 90 percent as determined by ground truthing.

Objectives

The objectives of the land-use and information management element are:

1.) To provide efficient and powerful data management capabilities to the water resource monitoring program within the ARMO network.

2.) To produce or procure accurate land-use coverage for watersheds (where practical) above ARMO Network parks as prescribed in the schedule section.

3.) Analyze GIS data-layers to determine the spatial distribution of selected morphological characteristics and temporal changes in land use.

4.) Use monitoring results to investigate correlations between the environmental variables, morphological characteristics, and land use factors at all spatial scales (i.e. site, riffle, reach, sub-basin, and watershed).

Criteria for selecting area of coverage for land-use mapping

Land-cover mapping requirements relative to each of the ARMO parks were established based on the following criteria:

A.) Large river based parks (BUFF and ONSR).

1.) The area of coverage should be the watershed.

2.) The coverage should include areas that contribute groundwater to the watersheds in recognition of documented inter-basin groundwater transport concerns associated with karst terrains.

B.) Satellite parks (HOSP, PERI, GWCA, and ARPO).

1.) The area of coverage should be the watershed as long as the watershed area is reasonable and the upstream watershed area/park area ratio is less than 10.

2.) If the watershed area/park area ratio is greater than 10, land-use monitoring will be done on a sub-basin which is more proximal and relative to the park, as determined by the hydrologist at BUFF.

Data Management

A GIS is capable of inputting, storing, manipulating, analyzing and outputting georeferenced data. The power of a GIS is its ability to tie attributes about a location to the place it represents on the ground and output maps to display its geographic extent and associated attributes. Management of large and complex GIS and other data-bases that are intended to be accessible for all time must incorporate the concept of metadata (data about data) which describe the content, quality, condition, location, and other characteristics of the data. The Federal Geographic Data Committee (FGDC) identifies three major uses of metadata. First, metadata helps to organize and maintain an organization's investment in data. Second, it provides information to data clearinghouses. Finally, metadata aids in data transfer. The creation of metadata will be a necessity as the amount of digital geospatial data and the number of georeferenced sampling points and associated data will be quite large and ever expanding.

Metadata protocols will follow the standards outlined and approved by the Federal Geographic Data Committee (FGDC) in their publication *Content Standard for Digital Geospatial Metadata* (FGDC-STD-001-1998). The *FGDC Standards Reference Model* defines the expectations of FGDC standards, describes different types of geospatial standards, and documents the FGDC standards process. The *Standards Directives* provide additional guidance to the FGDC Subcommittees and Working Groups developing standards and document the practices of the FGDC Standards Working Group.

Data Reporting

Summary reports concerning land use in the watersheds or study areas associated with the ARMO parks will be made available in the same year that the land-use classification work is completed for a given unit. All GIS data available at the end of the first five years will be used to compare and search for correlations with the water quality, physical habitat, biological and other site or reach-specific data. The comprehensive ten-year report, which is discussed in more detail in the schedule section, will contain information concerning spatial and temporal land-use trends.

Element 5: Biologic Monitoring

Two groups of researchers have been in the process of developing biological monitoring programs for BUFF and ONSR for over ten years. Dr. Charles Rabeni and his associates with the Missouri Cooperative Fish and Wildlife Unit at the University of Missouri recently published a report entitled *A biological monitoring program for the Ozark National Scenic Riverways* (Doisy and Rabeni, 1999). At BUFF, Dr. Michael Mathis and his associates at the University of Central Arkansas have produced a series of reports and masters theses which culminated in the development of a final report entitled "*A biological monitoring program for Buffalo National River"* (Mathis, 2000). Both efforts utilized previously collected data, extensive literature reviews, watershed and reach specific issues, and statistical analyses which assessed the effects of space, time, and various data manipulations on the variability and required sample size of individual biometrics to develop biomonitoring programs to assess the health and integrity of these river systems and their tributaries. The strategy these researchers recommended focuses on macroinvertebrate communities.

While previous work has clearly demonstrated that macroinvertebrate communities should be the focus of biological monitoring, other trophic level communities should also be assessed at a less intensive scale. These communities include periphyton as representatives of the primary-level autotrophic community, and fish, which contain the bulk of top predator aquatic species and species with unique migratory attributes. For example, the construction of Bull Shoals dam on the White River above the confluence with the Buffalo River has effectively extirpated the once prominent channel and flathead catfish, and caused declines in three other fish species. This has occurred independent of any change in water quality, physical habitat, land use, or macroinvertebrates. In other words, while the monitoring program outlined to this point is critical, it would not have detected changes in one of BUFF's most important aquatic communities. Therefore, for this and other reasons, direct fish community monitoring is prescribed. U.S. Geological Survey NAWQA fish sampling techniques will be employed because they are scientifically defensible and have been shown to accurately detect community impairment with a reasonable amount of sampling and analysis effort.

An efficient biomonitoring program must be designed to minimize natural variation so that effects due to human perturbations may be detected. Impacts of some stream perturbations such as organic pollution are relatively easy to detect, while others require more extensive effort, skill, and expenditure. Consequently, various levels of assessments on three trophic levels of organisms will be utilized. The primary level utilizes USGS-NAWQA protocols to measure periphyton production. The second level uses USGS NAWQA techniques to collect macroinvertebrate samples, which are processed and analyzed using techniques and community metrics recommended by the researchers. The third level uses USGS NAWQA fish community sampling protocols, calculations of fish community diversity, and comparison to the standard Index of Biotic Integrity (Karr et al., 1986) to monitor and assess changes in fish communities.

Objectives

1.) Implement a biomonitoring program using periphyton, invertebrates, and fish that will allow the determination of the biological health of the aquatic ecosystems by detecting changes over time or from one location to another.

2.) Provide baseline data needed for ancillary monitoring and research programs.

3.) Collect comparable data of known quality for use in other studies.

Criteria for establishing biological monitoring sites

1.) Biomonitoring sites and reaches should be established at or within the water-quality monitoring site locations and the physical habitat assessment reaches. This will allow a weight of evidence approach to be used to describe cause and effect between the various water-quality, flow, land-use, physical habitat and biological attributes of the aquatic systems.

2.) Periphyton and macroinvertebrate collections will be done within the same riffle from which water-quality samples are collected, and from one riffle above and one riffle below the water-quality riffle.

3.) Fish community sampling will be performed within the physical habitat assessment reaches for the length of six times the bankfull width of the stream channel and include riffle, pool, run, and glide habitats.

Biomonitoring Parameters

As alluded to previously, biological components are important to an integrated assessment of water quality because of factors such as 1.) sensitivity to a wide variety of natural and human environmental influences (for example, chemical constituents, hydrologic modifications, sedimentation, and thermal enhancement), 2.) increased analytical sensitivity due to bioconcentration of certain contaminants, 3.) integration of exposure to environmental influences over multiple temporal and spatial scales (for example, algae integrate exposure over several millimeters and for periods of several weeks, whereas fish may integrate exposure over many kilometers and for a decade or more), and 4.) a high degree of public interest and concern, particularly for endangered species. The following discussion explains how three biologic communities will be employed as monitoring parameters for the ARMO network.

Periphyton

Biological responses to anthropogenic nutrient inputs in lotic systems are observed first in periphyton communities. Algal blooms are experienced directly by park visitors and can reach nuisance levels during the summer. Because the Buffalo River and streams in some of the satellite parks are clear, warm-water system, they are especially subject to large-scale periphyton production, with algal blooms (spirogyra and horse-hair algae, among others) being the most common water-quality related complaint at BUFF. The aesthetic appeal of the river is reduced by floating mats of live and decaying algae, and turbidity has increased in tributaries beyond state standards due to suspended phytoplankton. How this algal biomass production relates to nonpoint source pollution, land-use activities, hydrograph periods, nutrient concentrations, and faunal communities needs to be evaluated through monitoring. It is likely that chemical, physical, and biological factors are resulting in different periphyton communities at sites in different land use settings in or near the ARMO network parks, resulting in the alteration of food chains and higher level community composition.

Quantitative periphyton samples will be collected using the PVC cylinder methods developed by the USGS NAWQA program and described by Porter and others (1993). Periphyton analysis in the ARMO monitoring network will focus only on measuring the Chlorophyll A content and ash-free dry mass (AFDM) of the sample and is not intended to utilize taxonomic procedures to provide community assessments. The Chlorophyll A and AFDM provides a quantitative estimate of primary productivity within monitored steam reaches and therefore an indication of nutrient enrichment within the system.

Macroinvertebrates

Macroinvertebrates are the most commonly used aquatic group for biomonitoring because they are ubiquitous in the aquatic environment, include a large number of species which respond differently to environmental stresses, are relatively easy to collect, and can be analyzed with many differing levels of precision and therefore effort. Probably the most important question regarding the application of biomonitoring to the ARMO network is determining an acceptable balance between the level of precision needed and the amount of effort and resources available to complete macroinvertebrate community assessments. For example, the USGS-NAWQA macroinvertebrate collection program in the Ozark Plateaus in the mid-1990s was designed to be painstakingly accurate. However, the large number of samples and detailed level of taxonomic resolution required to meet NAWQA macroinvertebrate protocols overwhelmed their system, and the samples collected have yet to be processed and analyzed. On the other hand, EPA rapid bioassessment techniques are rapid, can yield answers in the field, are statistically defensible, and commonly used, yet studies have shown they fail to provide the level of resolution required to detect most disturbance in the Ozarks, especially in the relatively protected Buffalo National River and Ozark National Scenic Riverways (Mathis, 2000; Doisy and Rabeni, 1999).

Habitat Selection – Both region specific works by Doisy and Rabeni (1999), and Mathis (2000), concluded that while overall characterization of macroinvertebrate communities must include multiple habitats, biomonitoring with the previously stated objectives should focus on the most diverse and easily sampled habitat type, the riffle/run. Three riffles will be sampled per site from within the physical habitat monitoring reaches.

Collection Techniques – Macroinvertebrate monitoring within the ARMO network will employ the semi-quantitative collection techniques developed by the USGS-NAWQA program (Cuffney et al, 1993). The Slack sampler, a modification of the Surber sampler, proved very useful for sampling riffles and runs during the NAWQA Program and have been shown to meet the needs of the ARMO network. In fact, analyses by Doisy and Rabeni (1999) showed that semi-quantitative data reduced both spatial and temporal variation as compared to quantitative data, and provide significant reductions in laboratory effort.

Sample Size – Doisy and Rabeni (1999) used a complex statistical analysis procedure and the mean and standard deviations from previously collected macroinvertebrate samples to determine the sample size necessary to achieve differing levels of statistical significance. Analyses of minimum detectable difference were performed for five common metrics (Simpson Index, taxa richness, total abundance, EPT richness, and Biotic Index). This analysis revealed a sample size of six per riffle provided an acceptable level of percent difference for all metrics except total abundance. They further concluded that sample size could likely be reduced if samples were collected from individual river systems as opposed to using regional data, and that sample size adjustments should be made using the results of the first year's sampling.

Sample Frequency – Samples will be collected seasonally on rotating years as described in Table 9. Previous work has indicated that winter sampling provides the best correlation between water-quality parameters and community metrics (Mathis, 2000). However, one of the objectives of this monitoring program is to evaluate natural variation (such as seasonal differences), therefore seasonal sampling will be employed.

Sample Processing – Specimens will be preserved in formalin in the field. In the laboratory, each sample is sorted from the organic debris using 10,000 micron and 300 micron mesh stacked sieves. The sample is thoroughly rinsed to help separate the coarse material from the finer material. The content of the lower sieve is scooped and rinsed into a plastic storage container using as little water as possible. The coarse material is then washed into the finer sieve and transferred to a second storage container in the same manner. The finer material is sorted using a modified zooplankton wheel on a dissecting scope at 30X power. The courser material is checked using a shallow pan at 30X power. All recovered specimens (including body parts) should be placed into double-labeled vials filled with 80% ethyl alcohol until further identification.

Subsampling – Subsampling techniques will be used as described by Caton (1991). In summary, specimens from a sample are placed in a tray with water and stirred to allow random distribution of individuals. A metal grid is then fitted into the tray and 3 squares from within the grid are randomly selected and the contents are removed. This process is continued until 100 specimens have been tallied and the number of squares required to produce 100 specimens is noted.

Quality Assurance – Random checks should be performed on 5% of the samples being processed. Organic materials being discarded after "picking" should be checked by a second person for missed specimens. To check the replicability of subsampling, one sample from each sampling period will be divided in half and then subsampled.

Level of Identification – To allow the level of precision needed to assess impacts in the ARMO network streams, genus level identification is required (Doisy and Rabeni, 1999). Insect identifications will be made using Merritt and Cummins (1996). Larval chironomids will be excluded from the identification based on the work by Doisy and Rabeni (1999) that found that inclusion of genus-level identification of chironomids did not add any precision to the metric analyses recommended later. Non-insect taxa will be identified to the level of class using Thorp and Covich (1991). After identification, voucher specimens for all taxa will be retained in a reference collection that is identified by a second taxonomist. Data from each sample will be entered into a standard Macroinvertebrate Laboratory Bench Sheet and entered into a computer spreadsheet for further analysis.

Selection of Metrics – Metrics were selected that achieve the original objectives of the monitoring program and the more specific biomonitoring objectives by assessing both community structure and community balance. Taxa richness, Ephemeroptera, Plecoptera, and Tricoptera (EPT) richness and the Simpson Index are good measures of the community structure, while community balance can be measured with the Biotic Index.

Data Management

Macroinvertebrate data is produced both in the field at the time of sample collection and in the lab when samples are analyzed. Standard field forms and sample labeling protocols will be used to record pertinent site information and keep track of samples. Tally sheets will be used in the laboratory to record genus level information relative to each specimen in the sub-sample being processed. Macroinvertebrate data will be stored in an excel spreadsheet data-base housed and maintained at BUFF. Data records will be tied to site and date parameters and will include field data and records indicating the number of individuals within all genuses.

Reporting

As stated previously, Taxa richness, Ephemeroptera, Plecoptera, and Tricoptera (EPT) richness and the Simpson Index will be the primary tools employed to analyze macroinvertebrate community structure. The community balance represented within individual samples will be assessed with the Biotic Index. Comprehensive biological monitoring analysis, graphical display, statistical analysis, and comparison with water quality, habitat, and land-use data will be employed to make recommendations to managers concerning the status and health of macroinvertebrate communities with the ARMO parks.

Fish

Community analysis offers several advantages for large-scale water-quality monitoring as compared to toxicity testing, biochemical characterization, or direct measurement of ecological processes. For example, community surveys directly relate to actual ambient conditions, take into account a large range of species representing a variety of environmental exposure pathways, eliminate the need to culture and maintain test organisms, and incorporate secondary effects that arise from the interactions of populations through competitive and predator-prey interactions. Community surveys remain the only means of directly assessing the biological integrity of a site and the only approach that is sensitive to toxicological influences, habitat degradation resulting from changes in land use, and cumulative impacts emanating from throughout the watershed or along migration corridors.

A fish community is a group of fishes belonging to a number of different species that occur in the same area and interact with each other. The structure of a fish community is determined by the species present, their relative abundances, life-stages and size distributions, and their distributions in space and time. Changes in fish community structure occur with natural or human changes in the physical and chemical characteristics of their environment. The ability to detect changes in fish community structure can be gained by developing an increased understanding of the factors that determine the distribution and abundance of fish species and identifying relations among patterns in fish community structure, physical habitat, and water chemistry conditions (Tonn and others, 1983).

The monitoring of fish communities is an essential component of water-quality assessment programs because fish are particularly sensitive indicators of water-quality conditions (Smith, 1971; Fausch and others, 1990). Human influences, such as changes in water chemistry or physical habitat modifications, can alter fish communities by disrupting their structures. Changes in fish community structure can be detected through changes in size components of the community, functional groups, species diversity, and relative abundance (Wootton, 1990).

Collection techniques - All fish community sampling will be conducted using USGS NAWQA Program protocols (Meador and others, 1993). Previous sampling by NAWQA (1993-1995) at BUFF and ONSR has provided a preliminary assessment of the amount of natural fluctuation present in fish communities from different times. To the extent practical, individuals will be identified to species in the field and released. Individuals that cannot be reliably identified in the field will be preserved for laboratory identification. Any individuals representing species newly documented in the streams (or sections of streams) will be kept as voucher specimens. Relative abundance (proportion of individuals) of each species will be calculated at each site. Sampling will be conducted during the summer when fish populations are most stable.

Sampling Reaches - Fish sampling reaches will lie within physical habitat monitoring reaches and include locations having associated water-quality, flow, and other biological monitoring data. Important considerations in the collection of a representative sample include sampling a distance of at least 6 stream widths, across at least two examples of each of two different types of geomorphic units (riffle, run, and pool, if representative), and using two sampling methods. Investigations and protocols cited in Meador and others (1993) suggest that in consideration of these factors, sampling 150 to 500 meters in wadeable streams and 500 to 1,000 meters in nonwadeable streams will adequately describe species richness and other measures of community structure.

Methods - Fish communities have an inherent level of natural variation depending on numerous hydrologic, climatic, ecological and other factors. This variability has been observed and quantified by previous USGS-NAWQA Program sampling at BUFF and ONSR and the broader Ozark Plateaus. Petersen's (1998) previous fish community investigations utilized repeated summer sampling over two years duration and typically yielded samples at sites that were 55 to 80 percent similar (67 to 76 percent similar at the Buffalo River sites samples in multiple years). Community differences between years seldom were sufficient to substantially modify interpretations about the site. Staff from the Arkansas Game and Fish Commission have offered to provide the equipment and expertise needed to complete the large river sampling efforts on the Buffalo River. It is anticipated that similar assistance can be found for Ozark National Scenic Riverways through the Missouri Department of Conservation.

Fish communities will be sampled using protocols summarized by Meador and others (1993) and used by Petersen (1998) to sample fish communities in the Ozark Plateaus as part of the NAWQA Program. These protocols were developed to meet the objective of describing fish community structure at a site--providing a representative snapshot of relative abundance and species richness from a realistic (reasonable effort, feasible, affordable) sample. The methods in the protocol were reviewed and approved by an advisory panel of fish ecologists from outside of NAWQA.

Electrofishing (sampling method 1) with a backpack unit, towed barge, and/or boat throughout a 150-800 meter reach will be supplemented with kick seining (sampling method 2) of riffles. Raw abundance and relative abundance data will be collected for each species. Small streams (generally those with a drainage area of 100 square miles or less) will be sampled using a single electrofishing pass; larger streams will be sampled using two passes. At each site fish will be sampled once in the summer. Restricting sampling to summer should reduce sampling variability related to spawning activity and unstable hydrologic conditions.

Data Management

Fish community data for each site will be recorded as fish are collected and identified in the field. Site-specific data will then be input to an excel spreadsheet and maintained at Buffalo National River. Paper-copies will also stored with the water quality and physical habitat field forms and notebooks.

Reporting

Several measures of community structure will be used to describe the fish communities. At a minimum these will include species richness, relative abundance per major family, and multivariate analysis. Two Way INdicator SPecies ANalysis (TWINSPAN), or detrended correspondence analysis (DCA), both types of multivariate analysis commonly used in community ecology, will be employed to yield a hierarchical approach which divides sites into groups containing similar communities. Drawing on examples from Richards and others (1996), Peterson (1998), Johnson and Gage (1997), ordination techniques will be used to compare fish community data with watershed, water-quality, and physical habitat data sets. These analyses will allow comparisons across multiple spatial scales and help identify links between watershed conditions and fish communities. Two sets of ordination analyses will be carried out: first, variation in the fisheries communities as a function of reach-scale physical habitat and water-quality characteristics will be quantified, and second as a function of watershed characteristics (e.g. land use, geology, watershed size).

Element 6: Special Projects and Contingencies

The hydrologists at BUFF and ONSR will supervise the implementation of this ARMO water resource monitoring program and must be given a sufficient amount of discretionary funds to use for special projects and contingencies. These funds will be used to 1.) leverage matching money to conduct special investigations which either support some aspect of the monitoring program or further quantify problems detected during the monitoring program, 2.) cover the costs of contingencies, such as major meter or laboratory equipment replacement, vehicle repairs, or to fund more intensive monitoring which deviates from the proposed schedule due to an unforeseen incident such as a hazardous material release, and 3.) allow for the conducting of specific projects which respond to emerging management issues and to better meet the objectives of the ARMO monitoring program.

Schedule

The document thus far has proposed a very ambitious, technically complex, multi-disciplined and labor intensive monitoring program. It would be impossible to do all the necessary activities each and every year with the amount of resources proposed. Furthermore, while documented changes are occurring in many of the ARMO units, the rate of change has, with a few notable exceptions, been measurable mostly in the order of decades. Therefore, a variable-intensity, rotating element scheme is proposed which is structured in such a way as to collect parameters at various temporal intensities, spreading out the work-load on the limited staff. Table 9 displays the ten-year monitoring cycle schedule.

The schedule reflects the need to develop a base-line dataset for the smaller ARMO satellite parks where relatively little water resource data has been previously collected. This is especially urgent at Hot Springs National Park because of the proposed Garland County landfill soon to be constructed near Bull Bayou about __ miles upstream from the 1.5 mile reach of this stream within the park. Straight-forward water-quality reports will be produced on a yearly basis for the satellite parks as that data-set begins to develop, with a more comprehensive water-quality report completed for every unit at the five-year mark. A comprehensive data-set will be available for each monitoring element and each unit at the end of the ten-year mark, and a multi-faceted data assessment will be completed at the ten-year mark.

Table 9: Ten -year schedule for the ARMO aquatic resource monitoring program.

Element	Year 1	Year 2	Year 3	Year 4	Year 5		Year 6	Year 7	Year 8	Year 9	Year 10	
1. Water-quality	ARMO	ARMO	ARMO	ARMO	ARMO	FIVE-YEAR REPORT	ARMO	ARMO	ARMO	ARMO	ARMO	COMPREHENSIVE 10-YEAR REPORT
2. Physical Habitat	*Start-up	HOSP	PERI	GWCA	ARPO		ONSR, main-stem	BUFF, main-stem	ONSR, tribs/ springs	BUFF, tribs/ springs	**Data analyses & report	
3. Stream Gauging												
Long-term	BUFF ONSR	BUFF ONSR	BUFF ONSR	BUFF ONSR	BUFF ONSR		BUFF ONSR	BUFF ONSR	BUFF ONSR	BUFF ONSR	BUFF ONSR	
Short-term (rotating)	*start-up	HOSP ARPO	GWCA PERI	ONSR, tribs/ springs	BUFF, tribs/ springs		ONSR main-stem	BUFF, main-stem	ONSR, tribs/ springs	BUFF, tribs/ springs	**Data analyses & report	
4. Land-Use	*start-up	HOSP	PERI	GWCA	ARPO		***GIS meta-data	ONSR	BUFF	***GIS meta-data	**Data analyses & report	
5. Biomonitoring												
Periphyton, Macro – invertebrates	ARMO satellites	ONSR	BUFF	ARMO satellites	ONSR		BUFF	ARMO satellites	ONSR	BUFF	**Data analyses & report	
Fish	*start-up	HOSP	PERI	GWCA	ARPO		ONSR main-stem	BUFF, main-stem	ONSR, tribs/ springs	BUFF, tribs/ springs	**Data analyses & report	
6. Special Studies	As Determined						As Determined					

Acronyms

ARMO – Heartland Aquatic Monitoring Network
HOSP - Hot Springs National Park, Arkansas
PERI – Pea Ridge National Military Park, Arkansas
ARPO - Arkansas Post National Historic Site, Arkansas
BUFF - Buffalo National River, Arkansas
ONSR - Ozark National Scenic Riverways, Missouri
GWCA - George Washington Carver National Monument, Missouri
ARMO satellites - PERI, ARPO, HOSP, and GWCA

*Start-up refers to the use of the first year's time and budget normally devoted to these elements to fill positions, purchase meters and supplies, set-up or expand capabilities at park-based laboratories, etc.

**Data analysis and report refers to using the tenth and final year of the monitoring cycle to produce an in-depth and comprehensive report with multi-variate statistical analysis for management as described in the text. Water-quality focused monitoring reports will also be produced each year for the satellite parks, and at the five year mark for all parks.
*** GIS meta-data refers to using two years to get the land-use and other spatial data into the GIS and concentrate on meta-data related requirements

Schedule Notes

Element 1: Water-quality - Seasonal water-quality monitoring is sufficient for monitoring purposes where many sites are utilized and an adequate base-line data-set exists. However, before seasonal sampling can be relied upon, a statistically representative base-line data-set must be available to: 1.) use for inter-site comparison, and 2.) to define the existing state of water-quality at a given site to which future monitoring is intended to show deviation from. Seasonal differences in water-quality are well documented in the Ozarks (Petersen et. al., 1998; Mott, 1997) as well as differences from year to year which result from differing hydrologic conditions. Therefore, the development of a sufficient base-line data-set must include monthly sampling spanning several years and it is paramount to collect water-quality data at a higher level of frequency for those sites where a background data-set is unavailable.

Sites that lack sufficient water-quality data are: 1.) all sites in the satellite parks, 2.) most tributaries and springs at ONSR, 3.) __ main-stem sites at ONSR (see Tables 3 through 5 for more details). All of the BUFF monitoring sites have an excellent data-base previously developed. Therefore, samples will be collected monthly from all sites lacking a pre-existing dataset for the *first two years*, and samples will be collected seasonally from BUFF sites and those sites at ONSR with sufficient pre-existing data. For the following three years, water-quality samples will be collected every other month at the sites lacking pre-existing data and seasonally at those sites with pre-existing data. After the first five years, and once 42 data points have been collected for each site, all sites will be monitored seasonally.

The first five years of sampling will elucidate the existence of areas with water-quality problems. It would be beneficial to allow personnel and resources freed-up through the reduction to seasonal sampling to conduct targeted monitoring in the problem areas. The nature and structure of this issue-specific monitoring will best be left to the hydrologists and aquatic ecologists in charge of the monitoring program, with appropriate direction from management, to develop and implement.

Element 2: Physical Habitat - The first year's funds and resources slated for physical habitat monitoring will be used to set up the BUFF-based GIS system, hire a GIS specialist, and bring all the relevant and available GIS coverages for the ARMO parks into the GIS. The second year will be used to collect physical habitat data for __ reaches within HOSP. The habitat work will be done in the late-fall or early-winter during one of the seasonal macroinvertebrate sampling trips when surveying work is easier due to leaf-off conditions, dormant cottonmouths, and temperatures more conducive to intensive field work. An added advantage of conducting habitat sampling early is that it will allow the field personnel and their supervisors to become familiar with the sampling reach prior to conducting biomonitoring activities. This same schedule rational applies throughout the remainder of the ten-year cycle.

Element 3: Stream Gauging –

*Long-term...*Discharge records extend for a considerable period of time at both BUFF and especially ONSR as indicated in Table 7. Continued operation of these gauges is critical to water resource monitoring. It is extremely beneficial to have these gauges operating at no cost to the National Park Service and they represent an important match of funds and will be utilzed at every opportunity to meet the goals of this monitoring program. For example, high-flow water quality monitoring will be initiated at long-term gauges.

Short-term (rotating) gauges - The streams, rivers and aquifers within the ARMO monitoring network are impacted mainly by nonpoint source pollution. Nonpoint source pollution is runoff driven, and during periods of rising and falling hydrographs pollution concentrations and loads can be orders of magnitude greater than during ground water dominated (base-flow) conditions. In fact, the bacteria loading to the Buffalo River from a tributary draining an agricultural sub-basin during just one runoff event was shown to exceed one million years of bacteria loading from a wilderness area during base-flow conditions (Steele and Mott, 1998). State standards for primary contact recreation waters have also been recorded in excess of 100 times greater than health based limits. Obviously it is important to measure storm-loads in the parks within this region.

The critical component in determining storm loads is knowing the discharge at the time samples are collected and the shape of the hydrograph produced by the runoff to allow integration. This is a grueling and sometimes dangerous task if monitoring personnel are required to construct this information through instantaneous discharge measurements under flood conditions. The installation of a USGS gauge at critical monitoring sites will provide this information in a very cost-effective and more accurate manner. This will allow park-based employees to grab samples from rising streams until the monitoring team can move to the location of the gauge and assume the monitoring responsibility. Samples are collected at more intense intervals (to be determined based on such factors as watershed size and level of accuracy desired, through recently developed formulas **site AWRC report in press**) during the rising side of the hydrograph and less intense intervals on the falling side of the hydrograph. Storm sampling requires from one to two days of field collections and follow-up laboratory analysis. Table 8 shows the yearly rotation of short-term gauges within the ARMO network. Exact locations of sampling sites will be prioritized by the BUFF and ONSR hydrologists in concert with park-based staff.

Element 4: Land-Use - The first year will be devoted to researching the best way to approach contracting the actual data-acquisition and analysis component of this element based on the latest developments in remote sensing. Actual data acquisition will begin in the second year with emphasis on acquiring appropriate data-bases for the satellite parks as described in Table 9. All watershed land-use information acquisition will be complete by year-8, which will allow the GIS specialist time to assimilate, manipulate, and integrate the land-use data with the other data-layers and complete all meta-data requirements. The tenth year will be devoted to the comprehensive data analysis and report production and then the cycle will repeat.

Element 5: Biomonitoring - Periphyton and macroinvertebrate sampling will be done seasonally on a rotating basis as shown in the ten-year schedule table. Fish sampling will be done in the summer on a rotating basis at those parks and locations also as indicated in Table 9.

Element 6: Special Studies and Contingencies – The timing, location, and nature of special studies conducted within the ARMO network will be left to the discretion of the BUFF and ONSR hydrologists, with appropriate input by unit managers.

References

Arkansas Department of Pollution Control and Ecology. 1992. Water quality inventory report, 1992. Arkansas Department of Pollution Control and Ecology, Little Rock, Arkansas.

Arkansas Department of Pollution Control and Ecology, 1995, Water Quality, macroinvertebrate, and fish community survey of the upper White River watershed, northwest Arkansas: Arkansas Department of Pollution Control and Ecology, Little Rock, Arkansas, 85 pp.

Bryant, C. T., and M. L. Mathis, 1997, An assessment of the macroinvertebrate community of the Buffalo National River. Master's Thesis, University of Central Arkansas, Conway, Arkansas.

Buchanan, T.J., and Sommers, W.P., 1984. Discharge measurements at gauging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A8, 65 p.

Caton, L.W., 1991, Improved subsampling methods for the EPA "Rapid Bioassessment" benthic protocols: Bulletin of the North American Benthological Society, 8:317-319.

Cashner, R.C., and J.D. Brown, 1977, Longitudinal distribution of the fishes of the Buffalo River in Northwest Arkansas, with some taxonomic considerations: Tulane Studies in Zoology and Botany, Vol. 19, No. 3 and 4, Tulane University, New Orleans, Louisiana, pp. 37 - 46.

Cuffney, T.F., Gurtz, M.E. and M. R. Meador, 1993, Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program: Open-File Report 93-406, U.S. Geological Survey.

Doisy, K., and Rabeni, C., 1999, A biological monitoring program for the Ozark National Scenic Riverways: U.S. Geological Survey, Biological Resources Division, Missouri Cooperative Fish and Wildlife Research Unit Contract Report, Columbia, Missouri, 52 pp.

Fausch, K.D., Lyons, J., Karr, J.R., and Angermeier, P.L., 1990, Fish communities as indicators of environmental degradation, in Adams, S.M., ed., Biological indicators of stress in fish: Bethesda, Md., American Fisheries Society, p. 123- 144.

Harrelson, C. C., Rawlins, C.L., and Potyondy, J.P., 1994, Stream Channel Reference Sites: An Illustrated Guide to Field Techniques: General Technical Report RM-245, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 61 pp.

Horton, R., and Johnson, J.E., 1993, Buffalo River creel census: Arkansas Cooperative Fish and Wildlife Unit, University of Arkansas, Fayetteville, AR.

Hudson, M.R., 1998, Geologic map of parts of the Jasper, Hasty, Ponca, Gaither, and Harrison quadrangles in and adjacent to Buffalo National River, northwestern Arkansas: U.S. Geological Survey Open-File Report 98-116, 1:24,000 scale w 20 p. text.

Jacobson, R.B. and Primm, A.T., 1997, Historical land-use changes and potential effects on stream disturbance in the Ozark Plateaus, Missouri: U.S. Geological Survey Water-Supply Paper 2494.

Jacobson, R., McKenney, R., Mott, D., and Putnam, C., 1998, Tributary land-use and aquatic habitat quality at Buffalo National River and the Ozark National Scenic Riverways: Proposal to National Park Service Natural Resources Preservation Program.

Jacobson, R.B., Femmer, S. R., and McKenney, R. A., in press, Land-use change and the physical habitat of streams—a review with emphasis on studies within the U.S. Geological Survey Federal-State Cooperative Program: U.S. Geological Survey Circular, 60 p.

Jacobson, R.B., and Pugh, A. L., in press, Riparian vegetation and the spatial pattern of stream-channel instability, Little Piney Creek, Missouri, US Geological Survey Water-supply Paper.

Johnson, L.B., and Gage, S.H., 1997, Landscape approaches to the analysis of aquatic ecosystems: Freshwater Biology, Vol. 37., pp.113-132.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser, 1986, Assessing biological integrity in running waters, a method and its rationale: Illinois Natural History Survey Special Publication 5, Champaign, Illinois.

Malcolm,J., Thornton, K.W., and Nix, J.F., 1986, Water Quality Monitoring Program, Buffalo National River, Boxley Valley, Arkansas: Ouachita Baptist University, Arkadelphia, Arkansas, 42 pp. + App.

Mathis, M.L., 2000, A aquatic biological monitoring program for Buffalo National River: University of Central Arkansas contract report, Conway, Arkansas.

McKenney, R. A., 1997, Formation and Maintenance of Hydraulic Habitat Units in Streams of the Ozark Plateaus, Missouri and Arkansas, [unpublished Ph.D. Dissertation] The Pennsylvania State University, 347 p.

McKenney, R. A., and Jacobson, 1996, Erosion and Deposition at the Riffle-Pool Scale in Gravel-bed Streams of the Ozark Plateaus, Missouri and Arkansas, US Geological Survey Open-File Report 96-655A, 171 p.

Meador, M.R., Cuffney, T.F., and Gurtz, M.E., 1993, Methods for sampling fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-104, 40 p.

Merritt, R.W., and K.W. Cummins (eds.), 1996, An introduction to the aquatic insects of North America: 3rd edition, Kendall/Hunt Publishing Company, Dubuque, IA.

Miller, A. J., and Jacobson, R.B., 1995, Channel planform in confining valleys [abs]: International Association of Geomorphologists, Southeast Asia Conference, Singapore, June 18-23, 1995, Programme with Abstracts, p. 57.

Missouri Department of Natural Resources, 1998, Public Notice of Section 303(d) Waters.

Mott, D.N., 1991, Water quality report - 1985 - 1990: Buffalo National River, Harrison, Arkansas, 36 pp.

Mott, D. N., 1997, Buffalo National River, Arkansas—Ten years of water quality monitoring: National Park Service, 36 p.

Mott, D.N., Hudson, M., and Aley, T., Nutrient loads traced to interbasin groundwater transport at Buffalo National River, Arkansas: *in* Proceedings of the 10th conference on research and resource management in parks and on public lands, George Wright Society, David Harmon, editor, Asheville, North Carolina, pp. 114 – 121.

National Park Service, 1995, National Park Service, 1997, Baseline Water Quality Data Inventory and Analysis, Ozark National Scenic Riverways: Vol I and II, Technical Report NPS/NRWRD/NRTR-95/70, Water Resources Division, Fort Collins, CO.

National Park Service, 1997, Baseline Water Quality Data Inventory and Analysis, Buffalo National River: Water Resources Division, Fort Collins, CO, vol I, 418 pp.

Petersen, J.C., 1998, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma—Fish communities in streams and their relations to selected environmental factors: U.S. Geological Survey Water-Resources Investigations Report 98-4155, 32 p.

Petersen, J.C., Adamski, J.C., Bell, R.W., Davis, J.V., Femmer, S.R., Freiwald, D.A., and Joseph, R.L., 1998, Water quality in the Ozark Plateaus, Arkansas, Kansas, Missouri, and Oklahoma, 1992-95: U.S. Geological Survey Circular 1158, 33 p.

Porter, S.D., Cuffney, T.F., Gurtz, M.E., and Meador, M.R., 1993, Methods for collecting algal samples as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-409, 39 p.

Porter, J.E., D.A. Evans, and L.M. Remsing, 1999, Water Resources Data, Arkansas, Water Year 1999: U.S. Geological Survey, Water-Data Report AR-99-1, Little Rock, Arkansas.

Rabeni, C.F., and Doisy, K.E., 1998, The distribution of benthic invertebrates among ecoregions and fish faunal regions Missouri streams: Journal of the North American Benthological Society.

Richards, C., Johnson, L. B. & Host G. E., 1996, Landscape-scale influences on stream habitats and biota. Canadian Journal of Fisheries and Aquatic Sciences, 53 (Suppl. 1): 295-311.

Siegworth, G., and Johnson, J.E., 1992, Affects of stocking channel catfish in a warm-water stream on angling success and the fish community: Arkansas Cooperative Fish and Wildlife Unit, University of Arkansas, Fayetteville, AR.

Smart, M.M., Jones, J.R., and Sebaugh, J.L., 1985, Stream watershed relations in the Missouri Ozark Plateau Province: Journal of Environmental Quality, v. 14, p. 77-82.

Smith, P.W., 1971, Illinois streams: a classification based on their fishes and an analysis of factors responsible for the disappearance of native species: Illinois Natural History Survey, Biological Notes 76.

Steele, K.F., and Mott, D.N., 1998, Storm and base flow water quality for Bear, Calf, and Tomahawk Creeks: Arkansas Water Resources Center, Publication no. 255, University of Arkansas, Fayetteville, Arkansas, 61 pp. + App.

Stewart, A.J., 1987, Response of stream algae to grazing minnows and nutrients: a field test for interactions: Oecologia, v. 72, p. 1-7.

Stephenson, T. R., and Mott, D.N., 1992, GIS analysis of slope and land use in a portion of the Buffalo National River basin: Park Science, Fall, 1992, Corvallis, OR.

Thorp, J.H., and Covich, A.P., 1991, Ecology and classification of North American freshwater invertebrates: Academic Press, San Diego, CA, 911 p.

Tonn, W.M., Magnuson, J.J., and Forbes, A.M., 1983, Community analysis in fishery management: an application with northern Wisconsin lakes: Transactions of the American Fisheries Society, v. 112, p. 368-377

U.S. Department of Agriculture, 1995. Watershed Plan-Environmental Assessment for Buffalo River Tributaries Watersheds, Final Report, USDA Natural Resources Conservation Service, Little Rock, Arkansas.

Wilde, F.D., and Radtke, D.B., 1998. National field manual for the collection of water-quality data--Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6,

Wolman, M.G., 1954, A method of sampling coarse river material: American Geophysical Union Transcripts, v. 35, no. 6, p. J951.

Wootton, R.J., 1990, Ecology of teleost fishes: Chapman and Hall, London, 404 p.